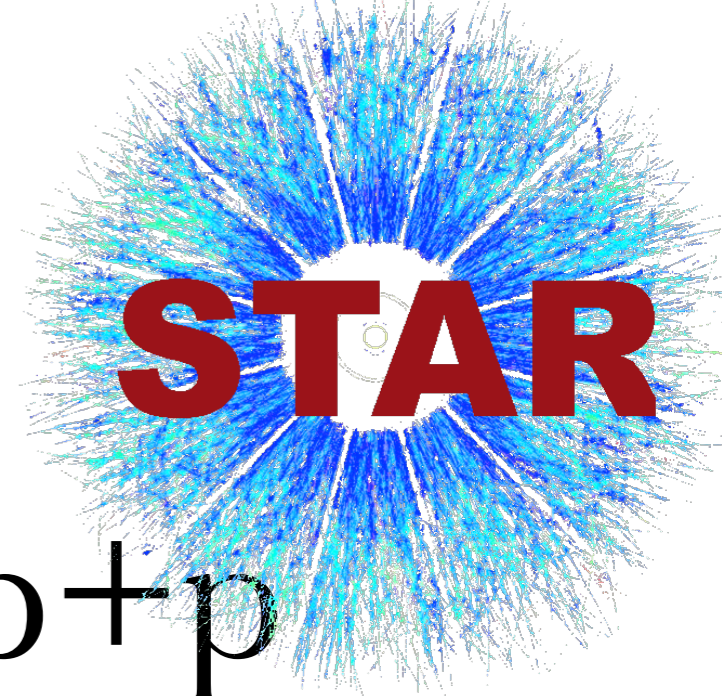**School of Collective Dynamics in High Energy Collisions**

J/ψ polarization in p+p collisions at √s = 200 GeV at STAR

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School of Collective Dynamics in High Energy Collisions
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Outline

- *Motivation and model predictions*

- *Decay angular distribution*

- *Electron identification*

- *J/ψ signal*

- *Extraction of J/ψ polarization parameter*

- *Polarization parameter vs J/ψ p_T*

- *Summary*

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Motivation

‣ J/ψ analysis in p+p collisions serves not only as a baseline for the J/ψ production in heavy ion collisions, it is very important tool for understanding the J/ψ production mechanism

‣ currently number of models with different assumptions regarding the J/ψ production mechanism seem to describe the measured J/ψ production cross section reasonably well; it suggest that other observables are needed

‣ *J/ψ polarization measurement at higher p_T is expected to have discrimination power between different models of the J/ψ production mechanism*
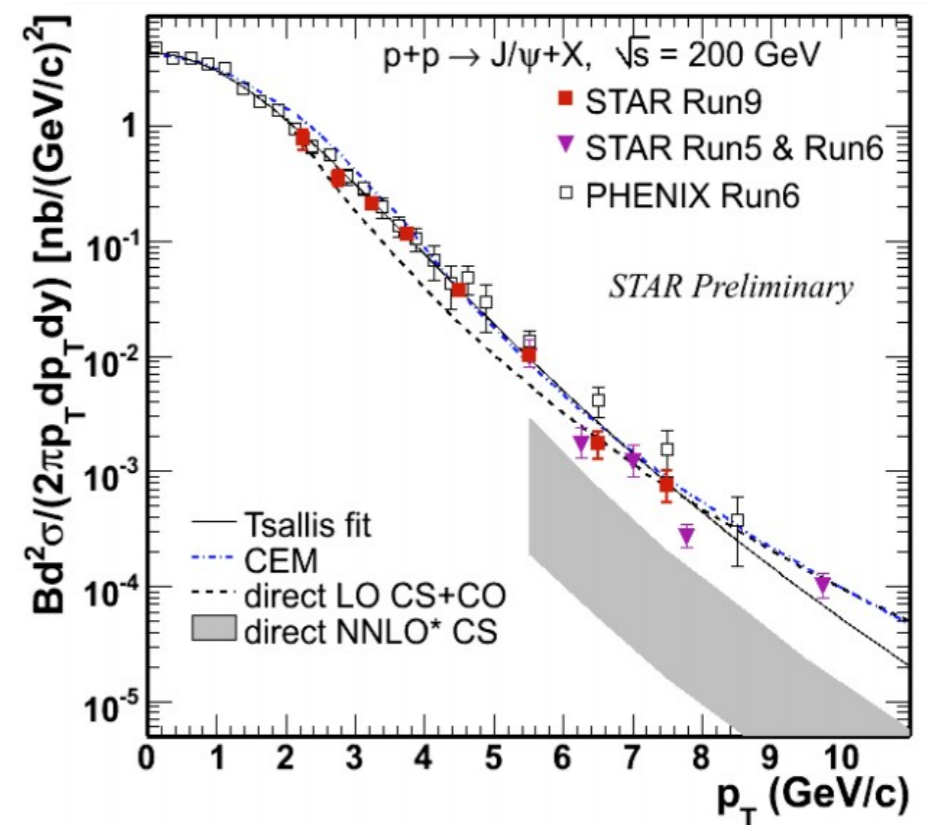
PHENIX: *Phys. Rev. D 82, 012001 (2010)*
STAR: *Phys. Rev. C80, 041902(R) (2009)*
Phys. Rev. D68, 034003 (2003)
Phys. Rev. Lett. 101, 152001 (2008)
JPG 37, 085104 (2010)
arXiv: hep-ph/0311048

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Model predictions

Various models have different, p_T dependent predictions regarding J/ψ polarization. Predictions at mid-rapidity:

- Color Octet Model (**NRQCD**) - transverse polarization at higher p_T, above 5 GeV/c, slightly longitudinal for lower p_T $1.5 < p_T < 5$ GeV/c [1,2]

- NLO Color Singlet Model - longitudinal polarization at low and mid p_T [3]

- Color Evaporation Model - has no prediction power regarding polarization [4]

*[1] Phys. Rev. D 62, 094005 (2000)*
[2] Phys. Rev. D 81, 014020 (2010)
[3] Phys. Lett. B, 695, 149 (2011)
[4] Phys. Rev. D 82, 012001 (2010)

Decay angular distribution

‣ J/ψ polarization is analyzed via the angular distribution of the decay electron pair

‣ J/ψ polarization is measured in the **helicity frame**

‣ θ angle is the polar angle between the positron momentum vector in the J/ψ rest frame and J/ψ momentum vector in the lab frame
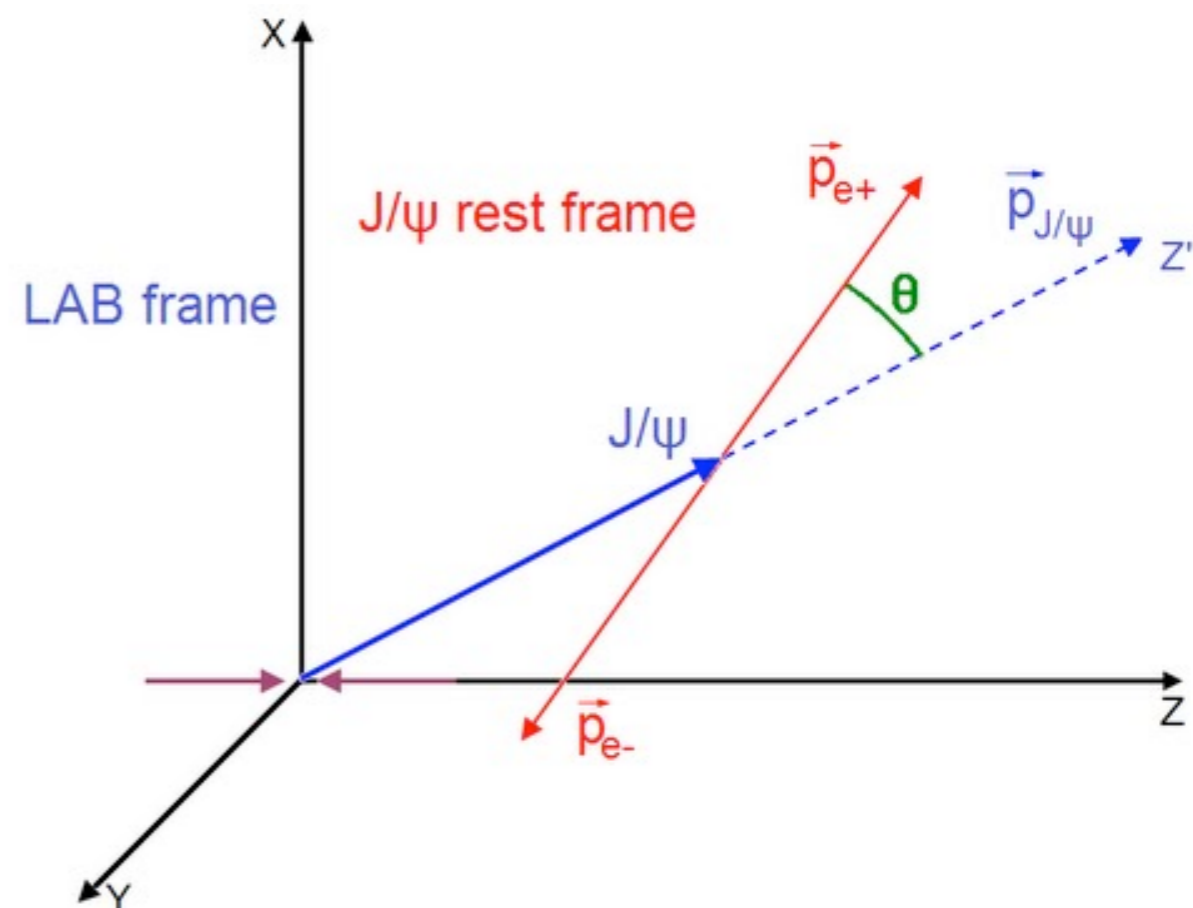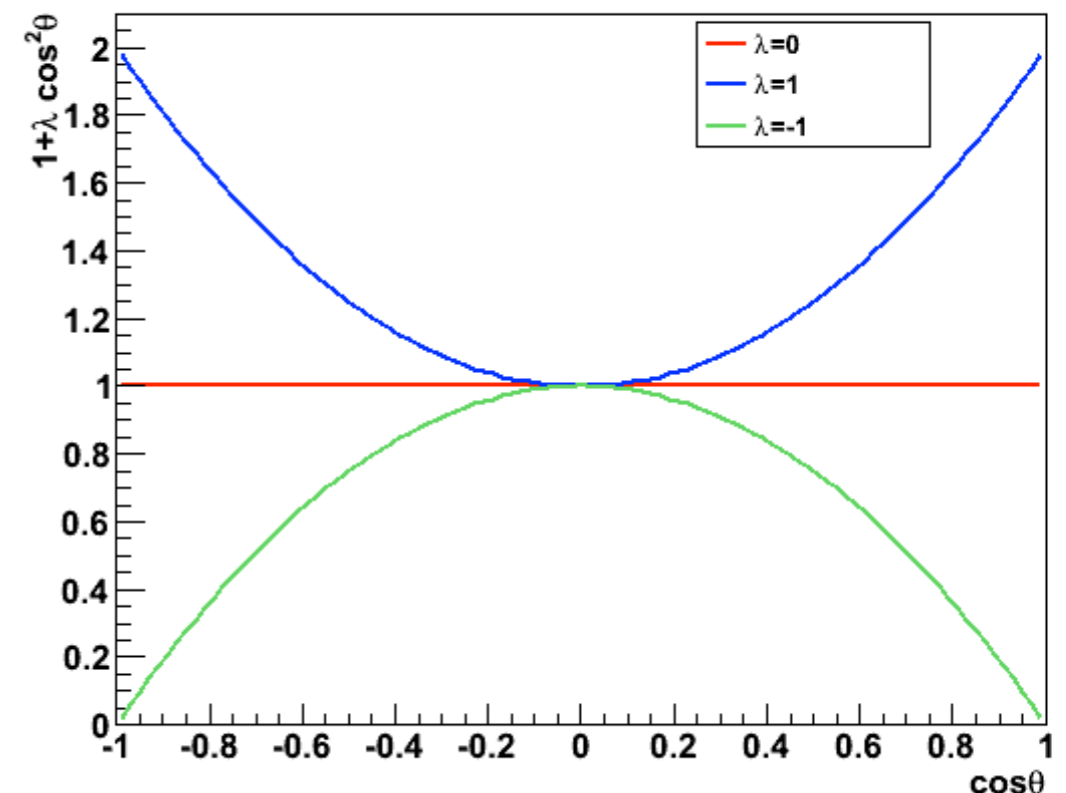
Polarization parameter λ

STAR

▸ the angular distribution, integrated over the azimuthal angle, can be parametrized:

$$\frac{dN}{dcos\,\theta} \propto 1 + \lambda \cos^2\theta$$

▸ polarization parameter λ contains both the longitudinal and transverse component of the J/ψ cross section:

$$\lambda = \frac{\sigma_T - 2\sigma_L}{\sigma_T + 2\sigma_L}$$

✓ λ = -1 - full longitudinal polarization

✓ λ = 0 - no polarization

✓ λ = 1 - full transverse polarization

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$\mathcal{J}/\psi$ reconstruction
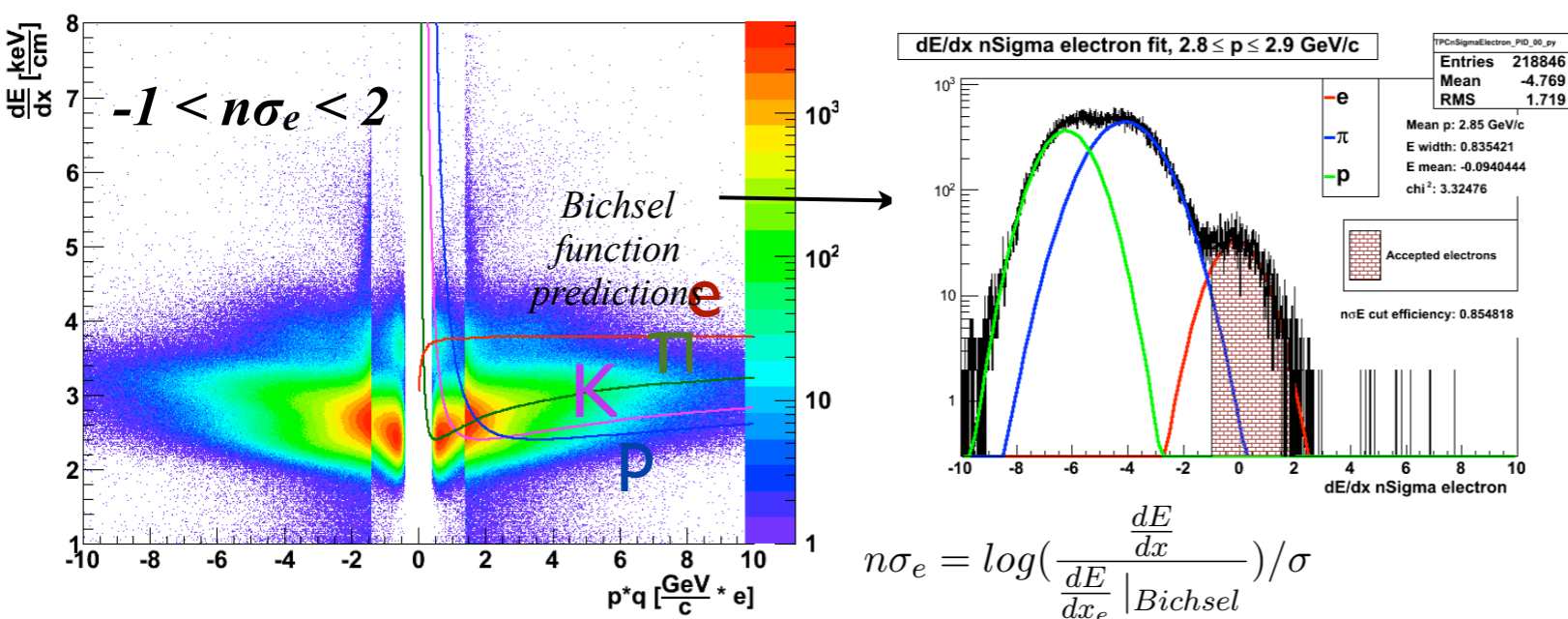
$\mathcal{J}/\psi \rightarrow e^+ e^-$ (BR 5.9%)

PID

‣ **TPC** - dE/dx - used for whole momentum range

$-1 < n\sigma_e < 2$

Bichsel function predictions

e
π
K
p

dE/dx nSigma electron fit, $2.8 \leq p \leq 2.9$ GeV/c

	Entries	218846
	Mean	-4.769
	RMS	1.719

e
π
p

Mean p: 2.85 GeV/c
E width: 0.835421
E mean: -0.0940444
chi²: 3.32476

Accepted electrons

noE cut efficiency: 0.854818

dE/dx nSigma electron

$$n\sigma_e = log(\frac{\frac{dE}{dx}}{\frac{dE}{dx_e}\big|_{Bichsel}})/\sigma$$

The **S**olenoid **T**racker **A**t **R**HIC
(STAR)

TOF BEMC   TPC
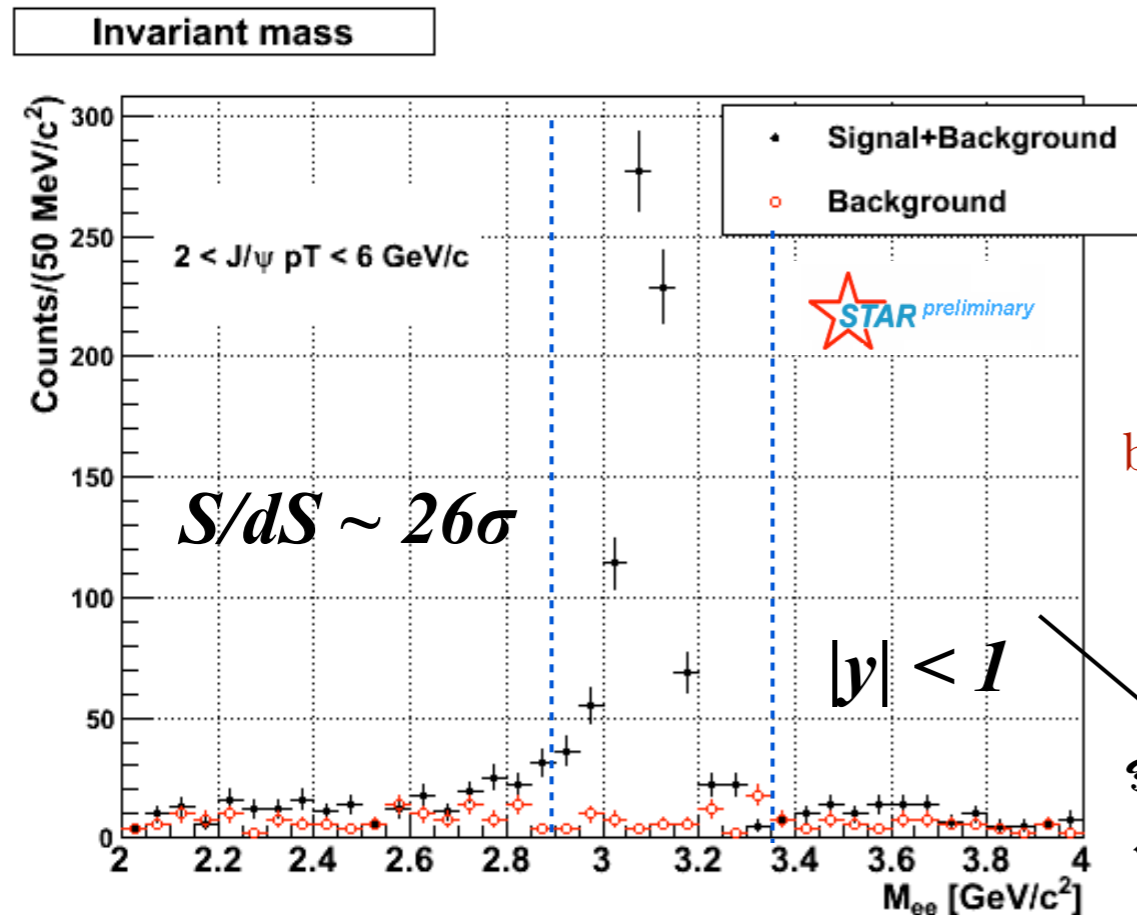
‣ **BEMC** - E, energy deposited in a tower -
for electrons E/p ~ 1

applied cut: E/p > 0.5, for p ≥ 1.4 GeV/c

‣ **TOF** (72% of full TOF in 2009) - β -
1/β cut applied for p < 1.4 GeV/c

β = pathLength/TimeOfFlight/c

$|1/\beta-1| < 0.03$

K
p
π
e

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J/ψ signal

dataset:

- p+p collisions at $\sqrt{s}$ = 200 GeV from year 2009

- ~ 30M events with HT trigger:
  2.6 GeV < E_T ≤ 4.3 GeV

- integrated luminosity ~ 1.5 pb[-1]

background obtained using like-sign technique:

$$N_{e^-e^-} + N_{e^+e^+}$$
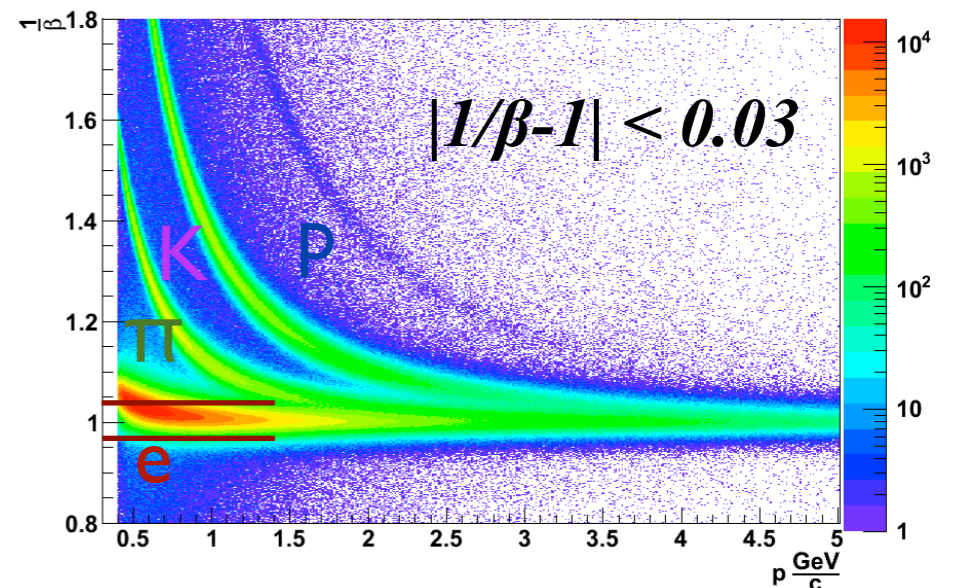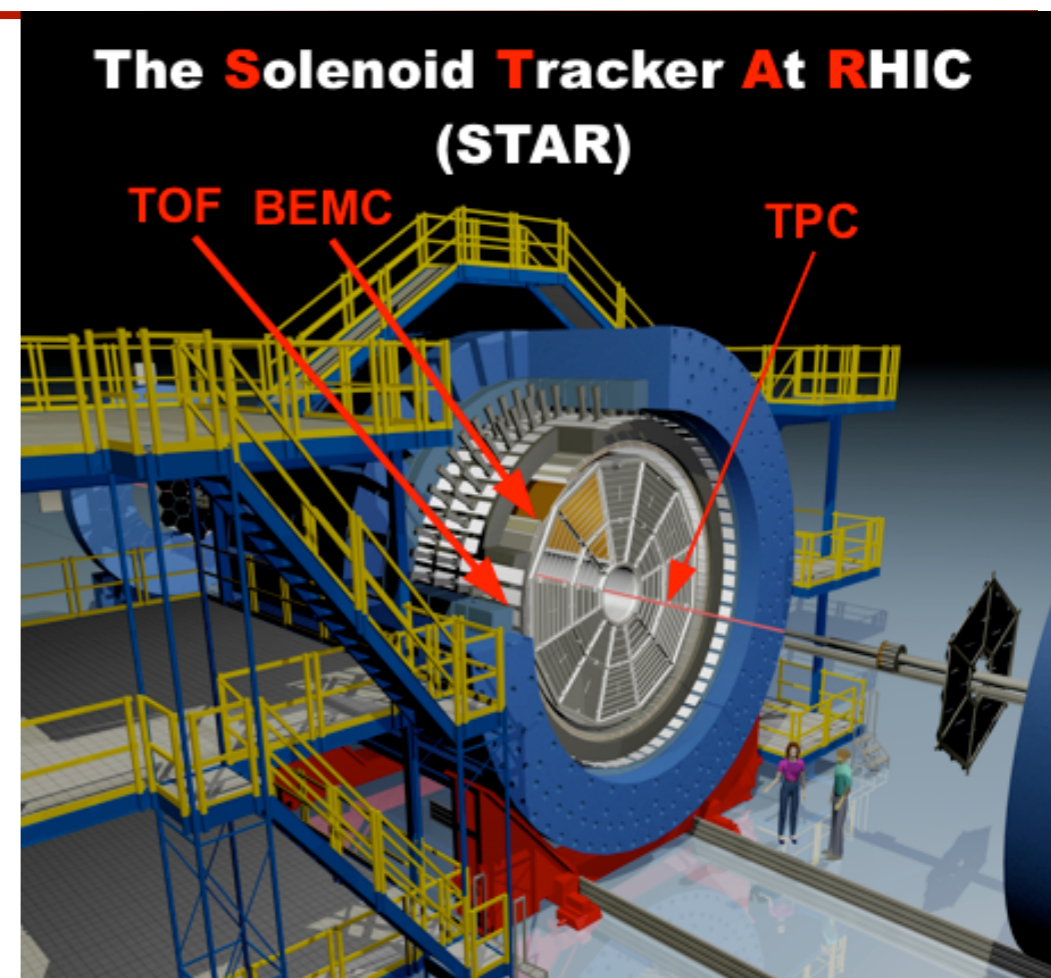
J/ψ mass window: 2.9 - 3.3 GeV/c²

significance: S/dS = S/√(S+2B)

- clear J/ψ signal with high significance of **26σ** in J/ψ p_T range: 2 - 6 GeV/c and rapidity: |y|<1

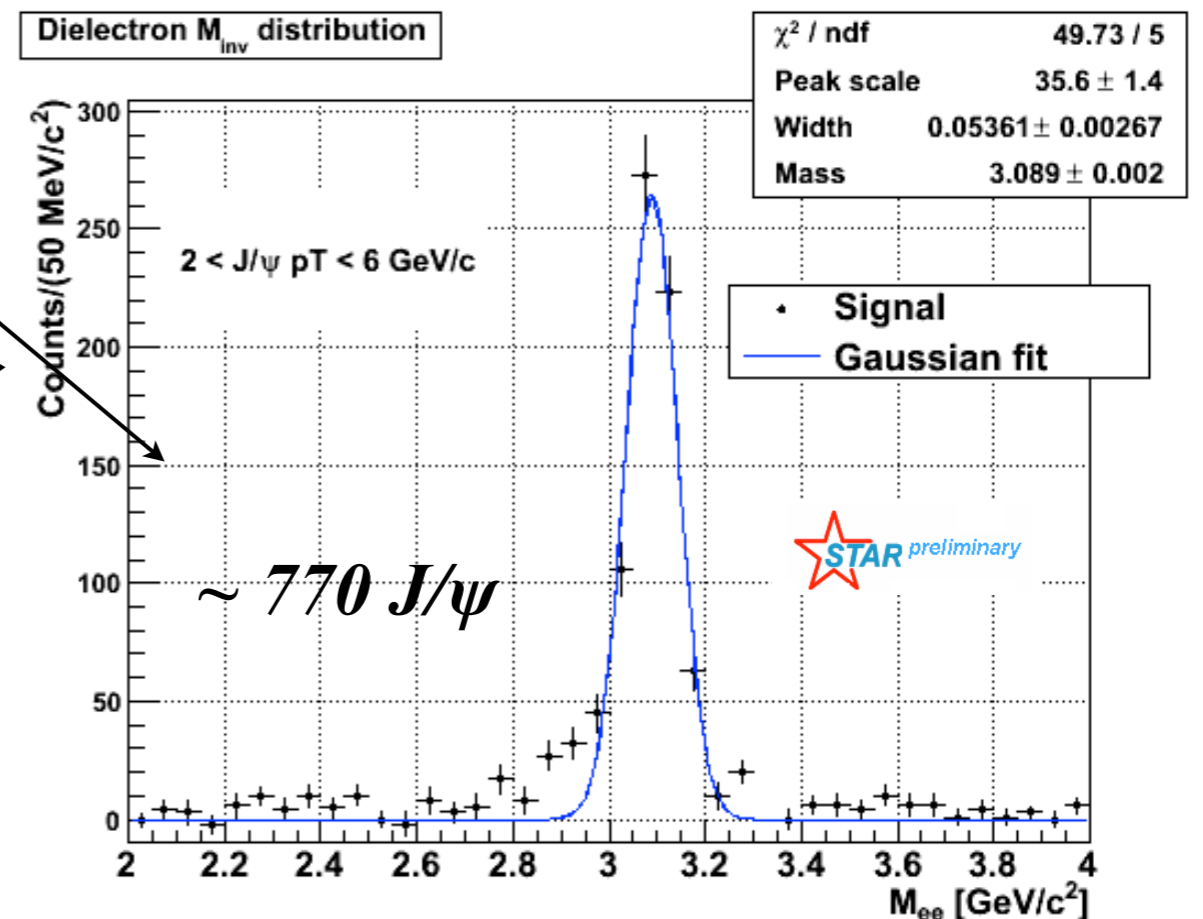- obtained number of J/ψs ~ 770 allow to split the signal into 3 p_T bins for polarization analysis

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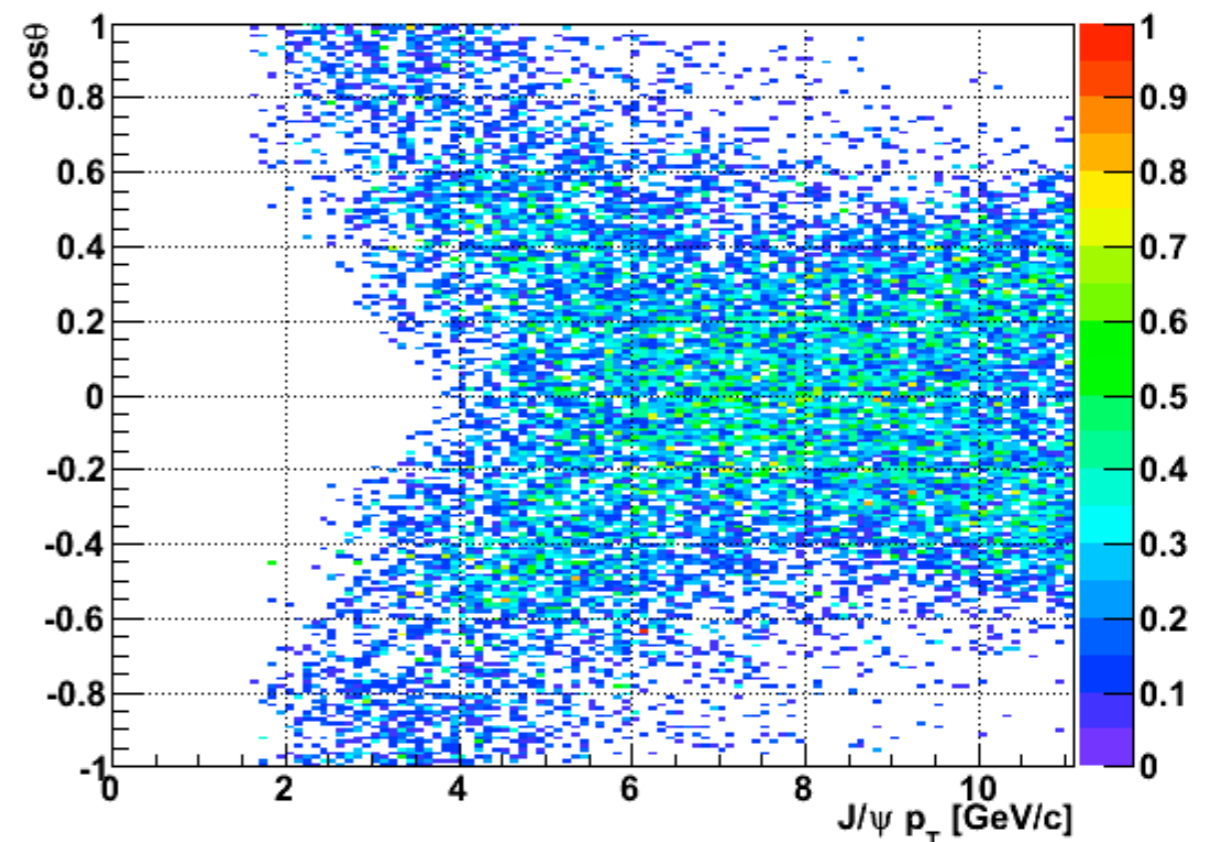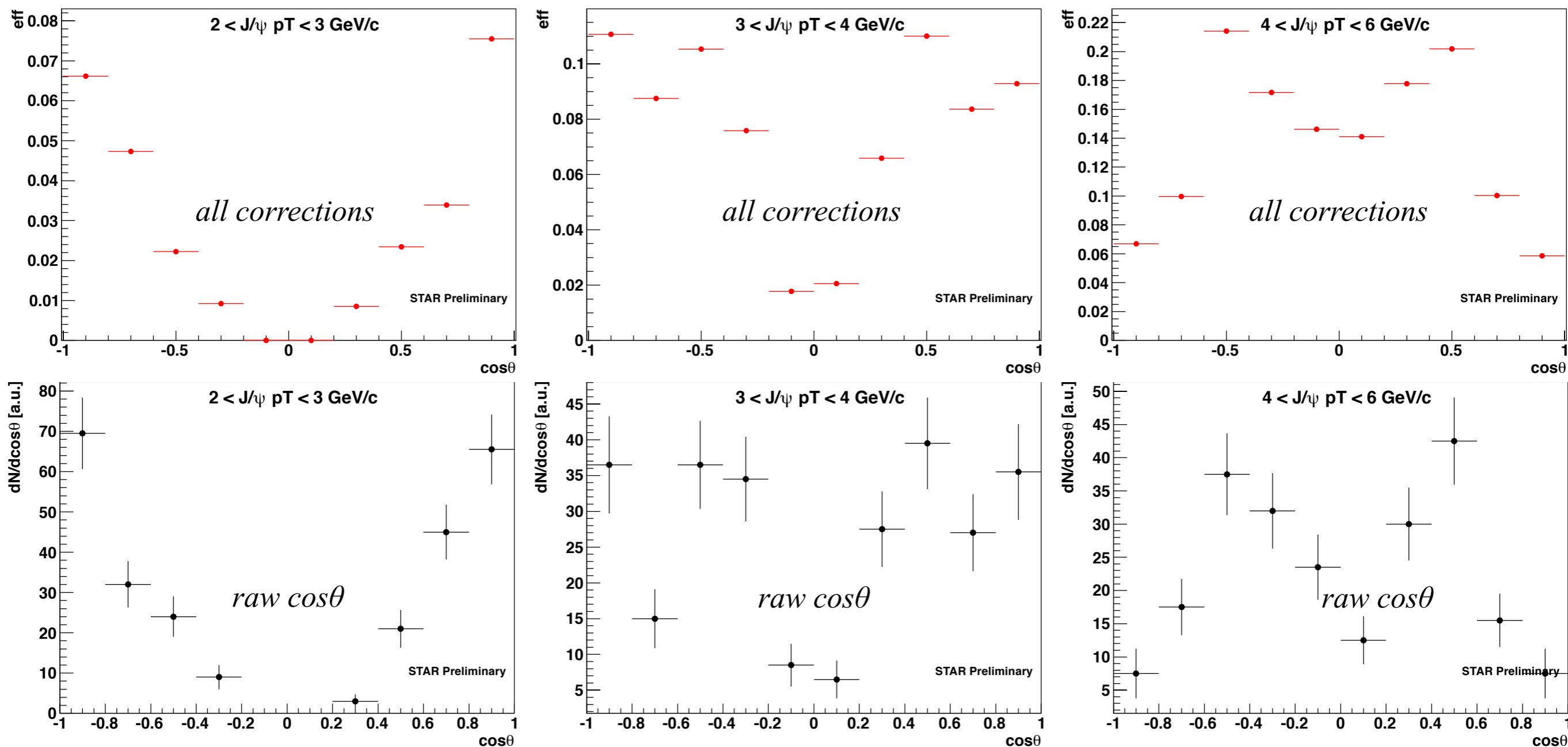# *Corrections*

- ‣ in order to get cosθ corrections MC J/ψs with uniform pT and y distributions were embedded into real events and the detector response was simulated

- ‣ then all data cuts were applied and obtained cosθ distribution was divided by the input cosθ distribution (in a function of J/ψ pT) and re-weighted according to the real J/ψ pT and y distributions

- ‣ obtained corrections are applied to raw cosθ distributions from data in 1GeV/c J/ψ pT wide bins

corrections include:

- ‣ *acceptance correction*

- ‣ *tracking efficiency*

- ‣ *electron identification efficiency*

- ‣ *HT trigger efficiency* - the most critical factor

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Total efficiency and uncorrected cosθ
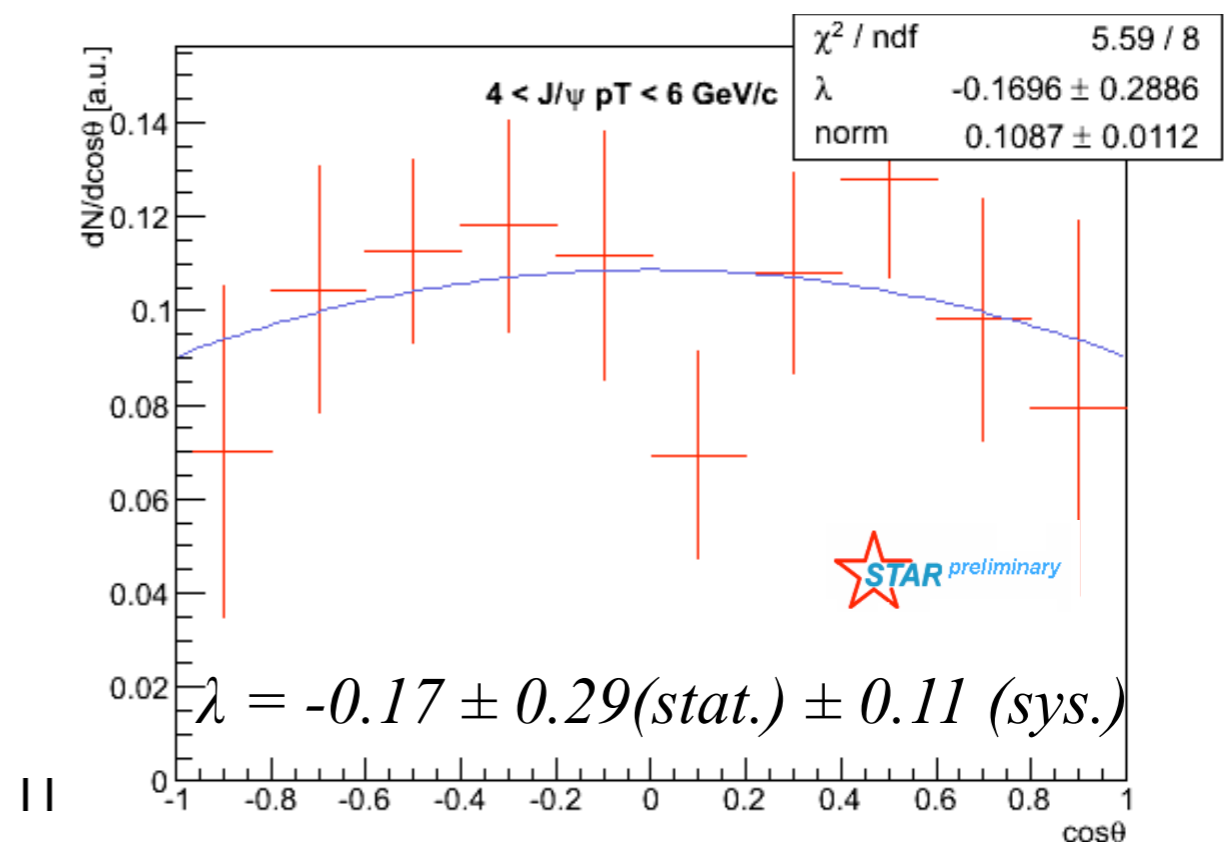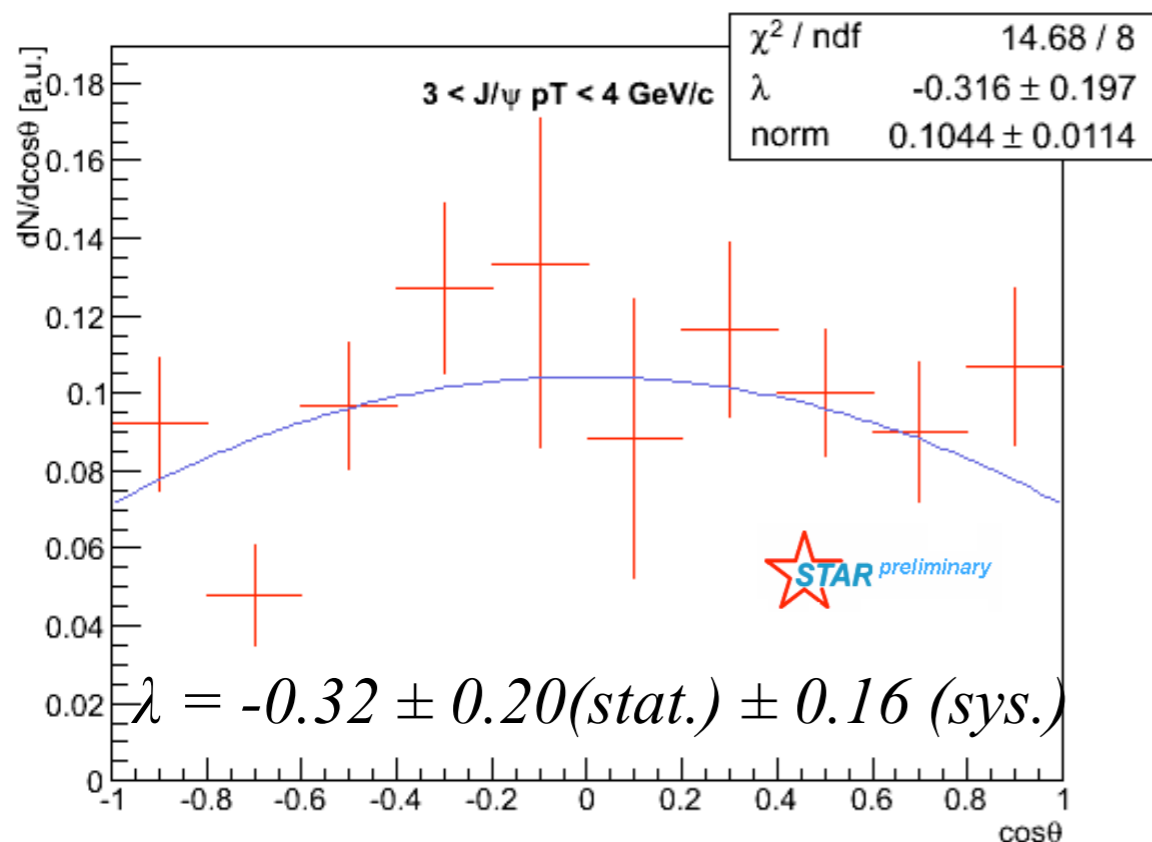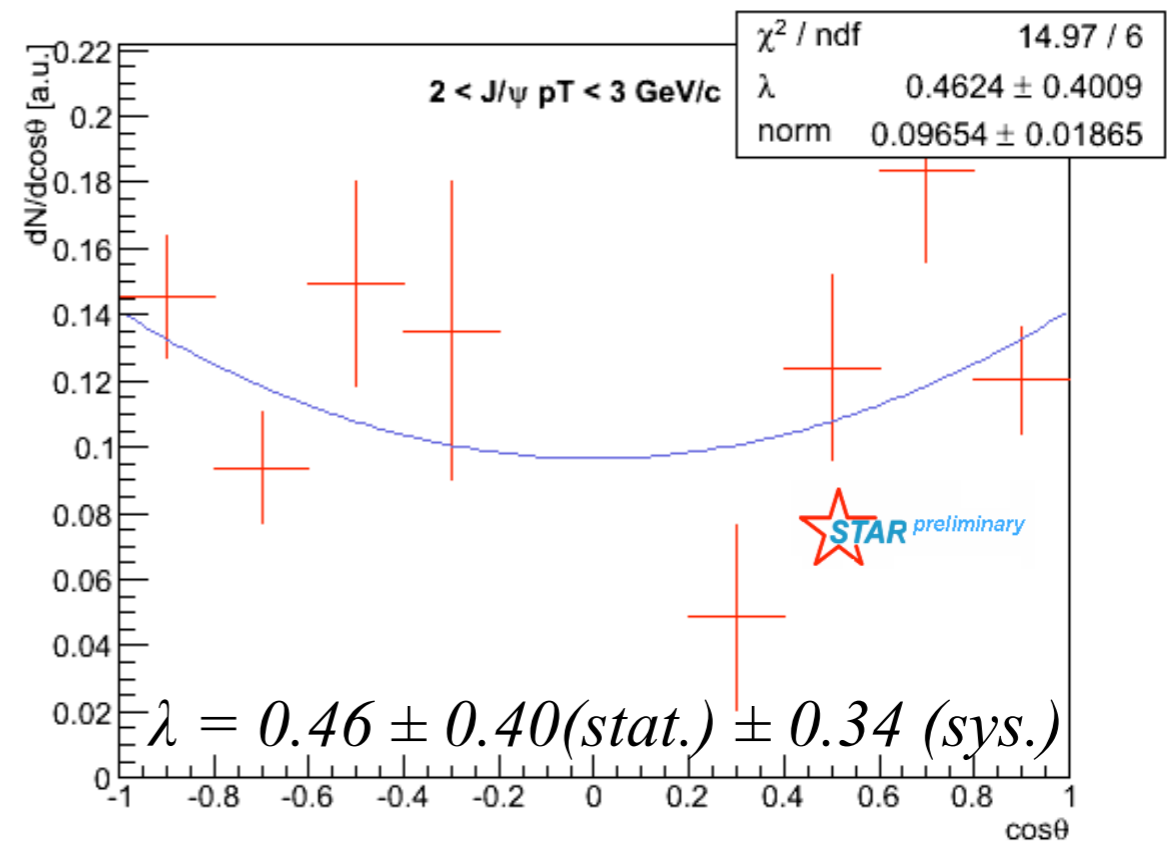

- uncorrected cosθ distributions are with the combinatorial background subtracted

- raw cosθ distributions from data are divided by corrections distributions in each J/ψ p_T bin in order to get corrected cosθ distributions
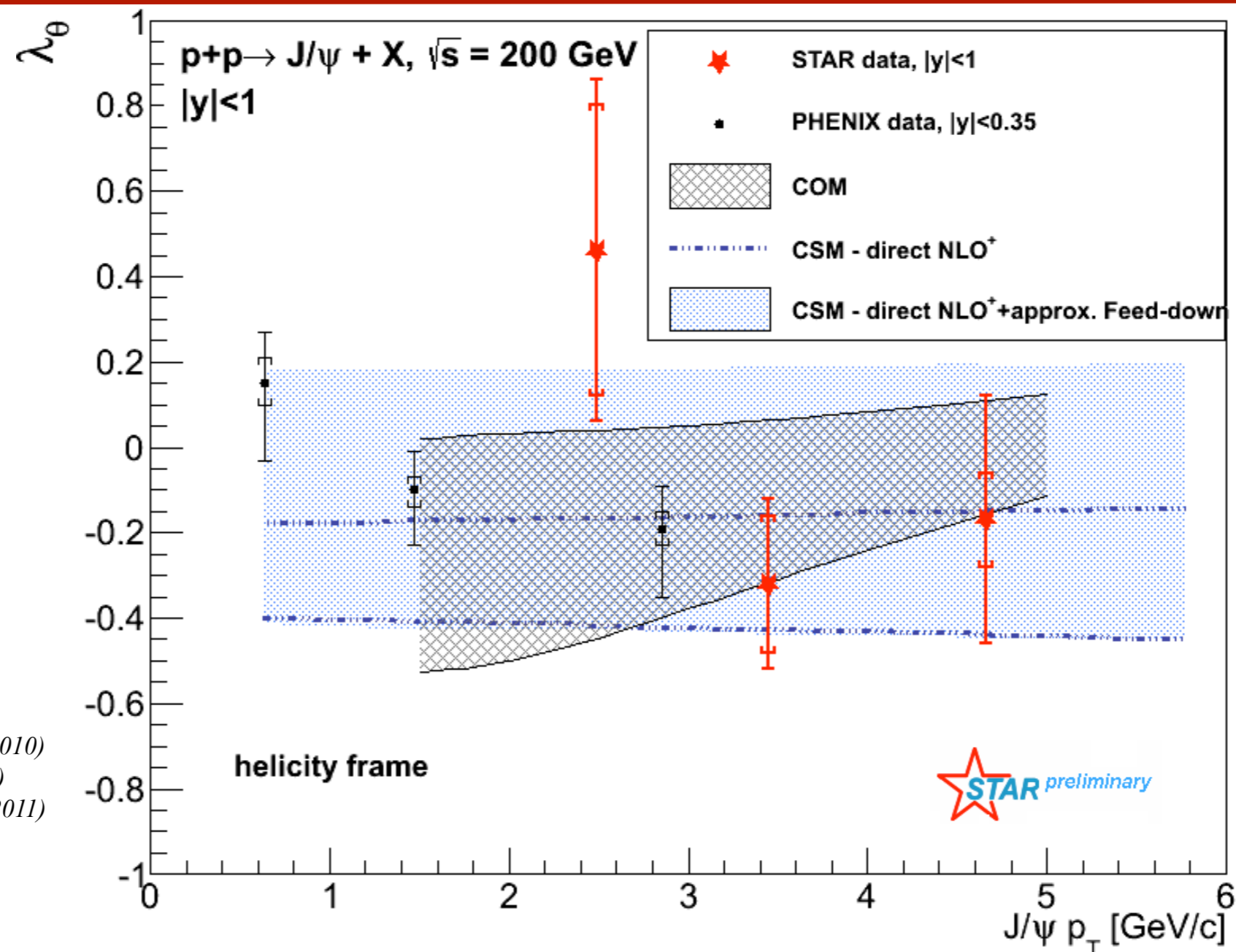
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Corrected cosθ distributions

- J/ψ polarization parameter is obtained by fitting

  $$norm(1+\lambda cos^2\theta)$$

  function to corrected cosθ without no constraints

- lines represent the most likely fit

- polarization parameter λ is extracted in 3 J/ψ p_T bins:

  2-3 GeV/c, 3-4 GeV/c and 4-6 GeV/c

χ^2 / ndf	14.97 / 6
λ	0.4624 ± 0.4009
norm	0.09654 ± 0.01865

2 < J/ψ pT < 3 GeV/c

STAR preliminary

λ = 0.46 ± 0.40(stat.) ± 0.34 (sys.)

χ^2 / ndf	14.68 / 8
λ	-0.316 ± 0.197
norm	0.1044 ± 0.0114

3 < J/ψ pT < 4 GeV/c

STAR preliminary

λ = -0.32 ± 0.20(stat.) ± 0.16 (sys.)

χ^2 / ndf	5.59 / 8
λ	-0.1696 ± 0.2886
norm	0.1087 ± 0.0112

4 < J/ψ pT < 6 GeV/c

STAR preliminary

λ = -0.17 ± 0.29(stat.) ± 0.11 (sys.)

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2012

$\mathcal{J}/\psi$ polarization result

PHENIX: Phys. Rev. D 82, 012001 (2010)
COM: Phys. Rev. D 81, 014020 (2010)
CSM NLO⁺: Phys. Lett. B, 695, 149 (2011)

‣ consistency between STAR and PHENIX results within errors

‣ STAR measurement extends the p_T reach to ~ 6 GeV/c

‣ STAR result is consistent with the COM and NLO⁺ CSM predictions

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Summary

‣ J/ψ polarization measurement from STAR at mid-rapidity in p+p collisions was shown.

‣ Polarization parameter λ is extracted in helicity frame in 3 J/ψ p_T bins.

‣ Obtained p_T dependent polarization parameter λ is consistent with NLO^+ CSM, COM models predictions and with no polarization within current theoretical and experimental uncertainties.

‣ Results are consistent with PHENIX polarization measurement at mid-rapidity, our measurement extends the p_T reach to ~ 6 GeV/c.

Thank you !